SPECIFICATION

TITLE of INVENTION

Electronic Volume Measuring Equipment

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CROSS REFERENCE to RELATED APPLICATIONS

Not applicable

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH or DEVELOPMENT

Not applicable

REFERENCE TO SEQUENCE LISTING, TABLE, OR COMPUTER LISTING COMPACT DISK

Not applicable

BACKGROUND of the INVENTION

Electronic Volume Measuring Equipment originated in response to the needs of the Post-Tensioning industry within the construction industry. In the late 1990's it was determined that previously approved construction techniques, materials, engineering and inspection used in the cement grouting of hollow ducts used in the post-tension industry were substandard. These ducts are used to carry post-tensioned steel reinforcing strand from one end of a concrete structure to the other to provide active reinforcement to the concrete. Such structures include bridges, buildings and tanks. After the installation of the post-tensioning strand is complete, the ducts are filled with a fluid cementitious grout to provide structural capacity and more importantly, corrosion protection for this reinforcing steel.

Routine inspection of bridges, particularly in Florida, uncovered substantial corrosion related defects and failures of the reinforcing steel. This steel is active reinforcement, under many thousands of pounds of force and literally holds the bridge together. Failure of this steel can result in catastrophic collapse. Further in-depth investigation by numerous state Departments of Transportation and independent engineering firms have uncovered widespread problems through out post-tensioned construction.

Examples of these structures include:

Sunshine Skyway Bridge, Tampa, Florida
Central Artery, Boston, Massachusetts
Airport Parking Garage, Raleigh Durham, North Carolina
Mid-Bay Bridge, Pensacola, Florida

To understand the problem in basic terms, the cementitious grout materials used to fill the ducts bled (separated into cement and water) and shrank, creating voids in the ducts and behind the anchorages for the post-tensioned steel. It is in these areas that corrosion can occur. Major structural damage caused by corrosion had been uncovered.

As part of an ongoing industry process, inspections are being conducted by many, if not all, state Departments of Transportation of these structures. Repairs are being instituted.

As part of the repair process, it is necessary to quantify the volume of the voids, both in the ducts and behind the anchorages. It is necessary to understand that many of these voids cannot be visually inspected or opened. The repairs must be conducted 'in the blind'. Thus it is necessary to quantify the extent of the problem using some sort of external testing equipment. Often, the only access to the voids is through a ½ inch hole, making visual inspection and conventional repair nearly impossible.

Much of the post-tensioning technology comes from Europe (France, Germany and Switzerland). The three main manufacturers of this equipment in the United States have ties to their European counterparts.

The equipment used by the European construction community to determine the volume in voids is a mechanical analog air measuring device first designed in the 1970's- 1980's. The equipment in use today was built at that time.

Additional uses include identifying unused volume in partially filled fuel tanks or chemical containers, pressure vessels, sealed piping systems, and other air tight systems.

The need arose to have modern electronic equipment; easier to use, smaller and more efficient. This has been invented by Guy Dickes, Baltimore, Maryland USA.

BRIEF SUMMARY of the INVENTION

Electronic Volume Measuring Equipment utilizes electronic gas mass flow technology in a manner to provide accurate volume measurement of air tight containers, voids in concrete, other air tight structures and containers and tanks. There are three variations of the process.

The first process involves pumping air (or other gas) through the device into the void or container.

The second involves evacuating air from the void or container, and allowing air to rush back into the void through the device to measure volume.

The third involves evacuating air from the void or container through the device to measure volume.

The advantages of the Electronic Volume Measuring Equipment include portability and accuracy, one version fits into a 26 inch by 10 inch by 10 inch tool box. Another version fits within a 20 inch by 10 inch by 8 inch NEMA4 electrical box. Accuracy is approximately 99%. In Contrast, the European mechanical model weighs several hundred pounds, requires a rolling platform for support and its accuracy is suspect. There are no other known means of determining blind volumes.

Other advantages include ease of use and speed of results. The connection of the device to the void or container is via a 3/8 inch or ½ inch hose and the manifold or entrance valve is opened. Direct reading of the volume is attained from the digital output meter. The European equipment requires 1 inch hose and requires interpretation of an analog gauge and needles.

Other uses include measuring barrels and casks, fuel tanks, storage containers. Inert gases can be used in lieu of air for fuel tanks or other pressure vessels containing explosive or hazardous materials.

BRIEF DESCRIPTION of the SEVERAL VIEWS of the DRAWING

The drawings attach reflect the three current versions of the Electronic Volume Measuring Equipment.

Drawing 1:	Basic Equipment Lay-Out and Usage (Pressure Version)
Drawing 2:	Specific Internal Component Layout (Pressure Version)
Drawing 3:	Basic Equipment Lay-Out and Usage (Air Rushing Through Device into Evacuated Void or Container)
Drawing 4:	Specific Internal Component Layout (Air Rushing Through Device into Evacuated Void or Container)
Drawing 5:	Basic Equipment Lay-Out and Usage (Vacuum Drawn through Device)
Drawing 6:	Specific Internal Component Layout (Vacuum Drawn through Device)

DETAILED DESCRIPTION of the INVENTION

The Electronic Volume Measuring Equipment utilizes commercially available electronics and mechanical components in a manner differently than the purpose for which that equipment it was originally designed.

There are two primary components and numerous secondary components of this equipment. The primary components are the gas mass flow sensor and the digital read-out. The remaining components provide protection of the equipment and pressure or vacuum.

The primary equipment includes an electronic gas mass flow sensor that measures the volume of a gas passing through it. It was designed to measure gas flow rate rather than volume. This mass flow meter is connected electronically to a 'totalizer' digital read-out, to provide total gas mass, rather than gas flow rate. This equipment is typically used in an industrial or laboratory environment to measure gas volume.

By utilizing this equipment, and regulating pressure, volume determinations can be made of an air tight container or void.

MAJOR PARTS, Description and Usage

Air Intake Filter:	pleated paper type air filter to remove particulate dust
Compressor:	electric or hydraulic powered air device to compress air or other gas to pressures greater than 1 atmosphere greater than ambient pressure
Condensate Filter:	device used to remove condensed moisture from compressed air
Desiccant Filter:	device using silica gel or similar material to further remove moisture from the compressed air
In-Line Particulate Filter:	filter designed to remove fine dust created by desiccant filter from the air
Pressure Regulator:	high accuracy device designed to provide controlled, constant air or gas pressure to the system
Flow Controller:	needle valve assembly or similar device used to restrict air flow through the gas mass flow sensor to its design rating
Mass Flow Sensor:	electronic device designed to measure the mass of gas flowing through and transmitting this information using a variety of outputs to the digital read-out meter
Digital Read-out Meter:	electronic device that accepts output from the Mass Flow Sensor and totalizes flow readings into total volume and presents that information through a digital read-out panel
Vacuum Pump:	electric or hydraulic device designed to reduce pressure in a void or container to near perfect zero pressure conditions
Hose/Entrance Valve:	devices to connect Electronic Volume Measuring Equipment to the void, container or tank to be measured

PROCESS ONE: Pressurizing the Void or Container using Compressor or Compressed Gas:

The layout of components and sequence of operations is as follows (internal compressor):

Intake air filter > Compressor > Condensate Filter > Desiccant Filter > In Line Particulate Filter> Pressure Regulator > Flow Controller> Mass Flow Sensor/Digital Read-out Meter > Hose > Entrance Valve > Void/Container

Alternately- using compressed gas:

Compressed Gas Cylinder > Pressure Regulator > Flow Controller > Mass Flow Sensor/Digital Read-out Meter > Hose > Entrance Valve > Void/Container

Air is drawn through the intake air filter by the Compressor. This compressed air goes through the condensate filter to remove excess moisture. The compressed air continues through the desiccant filter to further remove moisture. The compressed air continues through the In Line Particulate Filter to remove and dust or desiccant particles. The compressed air is then reduced in pressure to one atmosphere (14.7 psi). This is the first step to providing accurate volume measurement. The controlled pressure air then goes through a flow controller valve to match it with the capacity of the mass flow sensor. Finally, the air goes through the mass flow sensor and into the void or sealed container.

The air is dried to improve accuracy through the mass flow sensor. The mass flow sensor uses a 4-20mA or similar output to provide an electronic signal to the digital read-out meter. The digital read-out meter is calibrated to the mass flow sensor.

One atmosphere pressure (14.7 psi, 29.92 inches of Mercury, 760 torr, 1013 millibar) is used for simplicity. Direct reading of the air mass volume from the electronic digital is possible without calculation. Essentially, one 'volume' of air is going into void or container.

Added benefits of Process One is that leakage in the void or container can be identified using a solution of 50% water and 50% household liquid soap applied manually or through spray apparatus. Leakage can also be identified audibly. An auxiliary port is provided to bypass the Mass Flow Sensor/Digital Read-out.

PROCESS TWO: Allowing Air to Rush into the Evacuated Void or Container

The layout of components and sequence of operations is as follows:

Intake air filter > Desiccant Filter > In Line Particulate Filter > Flow Controller > Mass Flow Sensor/Digital Read-out Meter > Hose > Valve > Void/Container

In Process Two, the void is evacuated using a high vacuum pump. After the void is evacuated, the entrance valve is opened, allowing air to flow through the equipment as in

Process One. Air at sea level is at 14.7 psi, providing nearly the same level of accuracy as with Process One. Again the Desiccant and In Line Particulate Filters condition the air prior to going through the mass flow sensor.

PROCESS THREE: Evacuating Air through the Mass Flow Sensor

The layout of components and sequence of operations is as follows:

Container/Void > In Line Particulate Filter > Flow Controller > Mass Flow Sensor/Digital Read-out Meter > Vacuum Pump

In Process Three, air in the void or container is drawn through the In Line Particulate Filter and flow controller prior to mass flow sensor and finally the vacuum pump.

In all of the above processes, commercially available parts are utilized. Physical connections between components are either brass or plastic plumbing parts.

Calibration is necessary for Process One, as accurate pressure control is required. A factory calibrated pressure gauge is used for establishing the one atmosphere pressure. A high accuracy pressure regulator (error less than 0.1%) is used.

In all cases, the flow controller is adjusted to limit the gas flow through the mass flow sensor to limit set by the manufacturer. This is accomplished by measuring volume over time. If necessary, the flow controller is closed down to slow the volume of gas through the sensor. The sensors typically have flow rates of 5 to 15 liters per minute. The flow controller is set such that the maximum flow through the sensor is less than the maximum set by manufacturer.

The basic physical law to be applied is 'Boyle's Law' which states that:

"The volume of a fixed mass of gas varies inversely with its pressure at constant temperature".

As an example, if we double the pressure in the same container, we have doubled the mass. Since this invention is doubling the pressure from atmospheric pressure at sea level to plus 14.7 psi, we have added one volume of gas to the container.